# NGSCB: Threat Models

- Our Threat Model
  - No Software-Only Attacks Against RHS
  - No Break-Once/Break-Everywhere (BOBE) attacks
- No Software-Only Attacks means…
  - No attacks based on micro-code, macro-code, adapter card scripts, etc.
  - Any attacks launched from the Web or e-mail are "software only"
- Protection only applies to the release of secrets

# “Booting” The Nexus

- Nexus is like an OS kernel, so it must boot sometime
- Can boot long after main OS
- Can shut down long before main OS (and restart later)

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    - Randomizing
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# Other Keys: Whose are they?

- Answer: Entities authorized by users to access key services
  - User's personal Keys
  - Service provider's Keys
  - Shared Keys

# Machine owner is in complete control

by users to access

owns nor has access to any

hip is circumscribed and may not even
entity relying on it.

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- No NCA can use key services without user permission

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- The MS nexus will run any application
  - The user will be in charge of the applications that he chooses to run
- The MS nexus will interoperate with any network service provider

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  - NGSCB applications do no run at elevated privilege
- NGSCB NCA is not debuggable
  - Yes it is.

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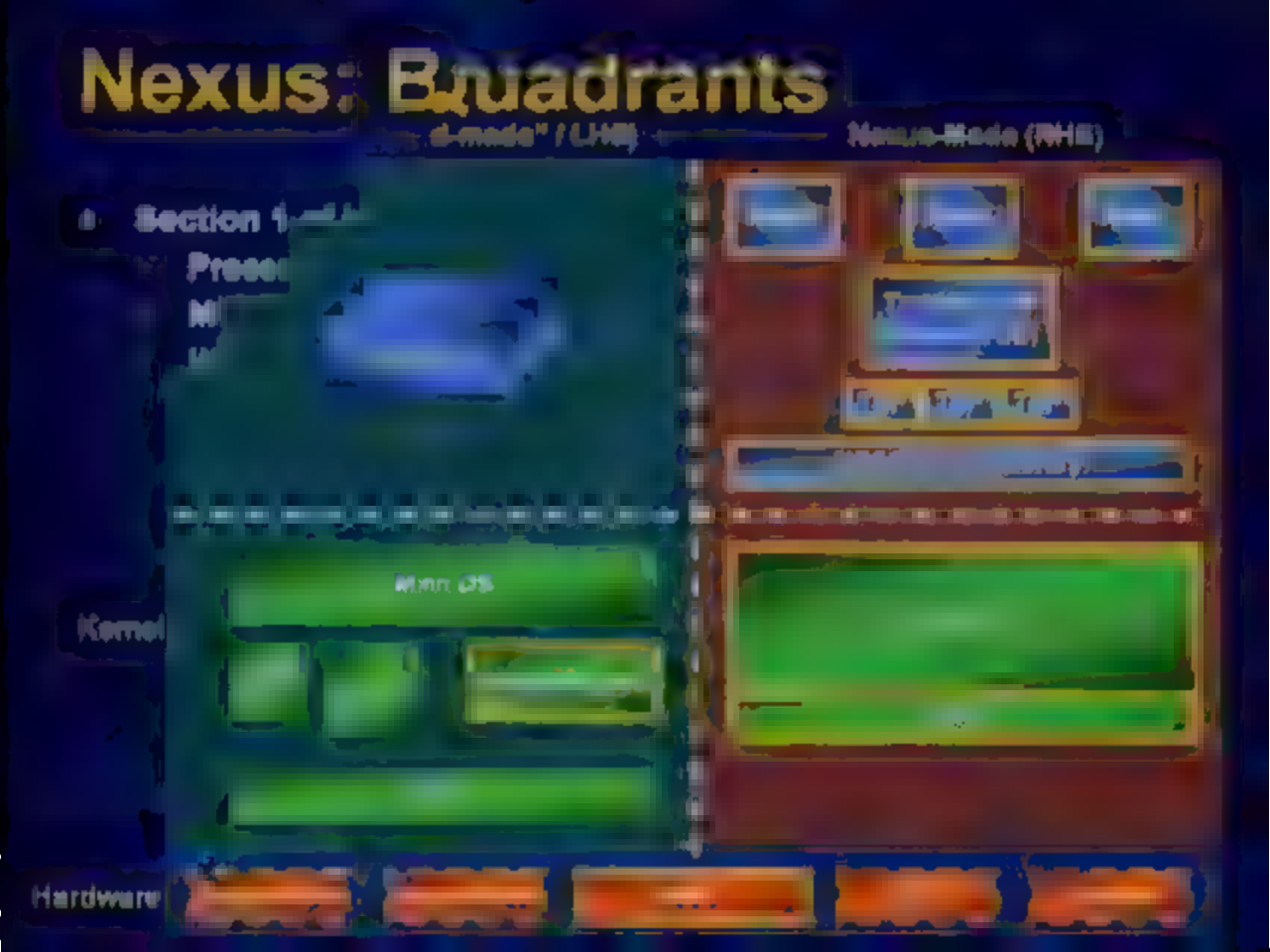
- Control will be exercised centrally
  - No central authorities required
  - Need for central authorities diminished
- TC will remove effective control of PC from its owner
  - Strengthens owner control


Nexus: Quadrants
Nexus-Mode (RHE)
Kernel
Hardware

# Nexus: Basic Environment

- Section 1 of Intro to Operating Systems Textbook
  - Process and Thread Loader/Manager
  - Memory Manager
  - I/O Manager
  - Security Reference Monitor
  - Interrupt handling/Hardware abstraction
- But no Section 2
  - No File System
  - No Networking
  - No Kernel Mode/Privileged Device Drivers
  - No Direct X
  - No Scheduling
  - No...
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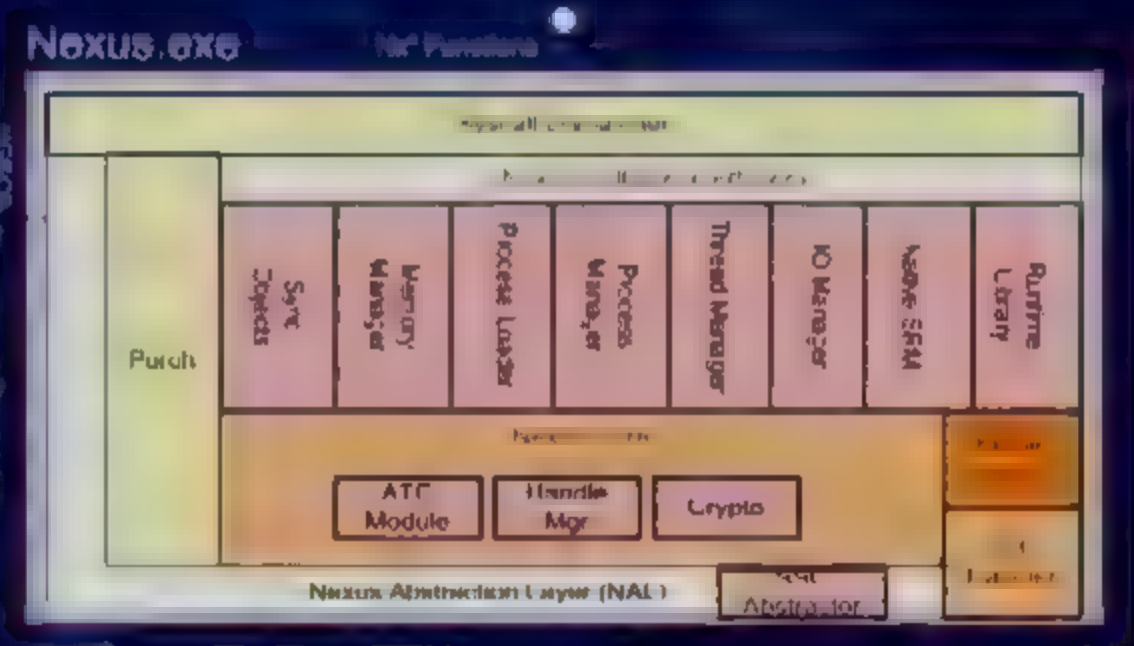
# Nexus: Basic Environment

- Virtualization of hardware fundamentals for Agents
  - Sealed storage, attestation, etc.
- Minimal Services
  - Trusted UI Engine
    - XML Based Graphical Services for UI
    - Input Routing/Focus Management
    - Minimum Fonts (Incl. Multiple Languages...)
    - Windows Manager
  - IPC
  - TSPs (Trusted Service Provider)
    - Run in User Mode Ring 3
    - Provide Services
    - Are "Drivers" for Trusted Input/Video

# Close-Up Of Nexus



# Code Identity

- Nexus
  - Cryptographic Hash
- Agents
  - Manifest (or rather hash of manifest)
    - Debugging Policy
    - Public Key
    - Corresponding Private key authorized to name cryptographic hashes of binaries that identify "this program"
    - Metadata

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# User Mode Debugging

- No agents are debuggable without a ch
  code identity debugged
  - Attestation reflects this change
- Debugging the LHS Shadow Pro debugged
  debugging the Agent
  - We've redirected the funct uses are different
    Context and Read and Writ their attestations are
  - We've redirected RHS
  - Thread control "ju
- Well behaved Auth
  processes will

# Secret Migration

- Caller gets to specify certain pr
  - What agents may unseal the set)
  - What hardware may unseal it anywhere
  - What nexus may unseal th
  - What users may unseal ...tEnvironment) →
- Agents shouldn't se
  - They should seal (somesecret)) →
    - which seals again
- Backup, reston
  possible usi ...blob(somesecret),
  and certif ...rgetEnvironment) → somesecret

# WIFM: Credential Based Security

- Single simple, flexible, scalable, distributed, credential based security model
  - Programs, use
  - Fine-grained, authorization language
  - General auther
- Manageable and
  - Non brittle
  - Administrable
  - Projects Secur
- Framework for policy enforcement
  - Desktop Lockdown
  - Policy assurance (Virus policy, ID6, ...)
- Supports migration of existing Windows security services

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# achine Partitioning
# or "How to keep the TCB Small"

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# Overview

- Requirements
- System Architecture

# Machine Partitioning or "How to keep the TCB Small"

# Overview

- Requirements
- System Architecture

# Mass Market Requirements

- Open architecture
  - Decentralized production of HW peripherals
  - Any SW runs
- Legacy
  - No fundamental changes to PC platform hardware
  - No fundamental changes to OS software (Windows)
  - Most peripheral hardware must work without changes
- Performance
  - Security features should not deteriorate performance significantly (at most a few percent).
- Cost
  - No significant increase in the cost of PC platform hardware

# Security Requirements

- Programs must be able to receive, process, output data without leaking or subversion
  - Confidentiality
  - Integrity
- Not necessarily availability

- Need high assurance for these properties
  - Should not depend on BIOS, option ROMS, device drivers, large operating systems

# System Architecture

# Existing Approaches

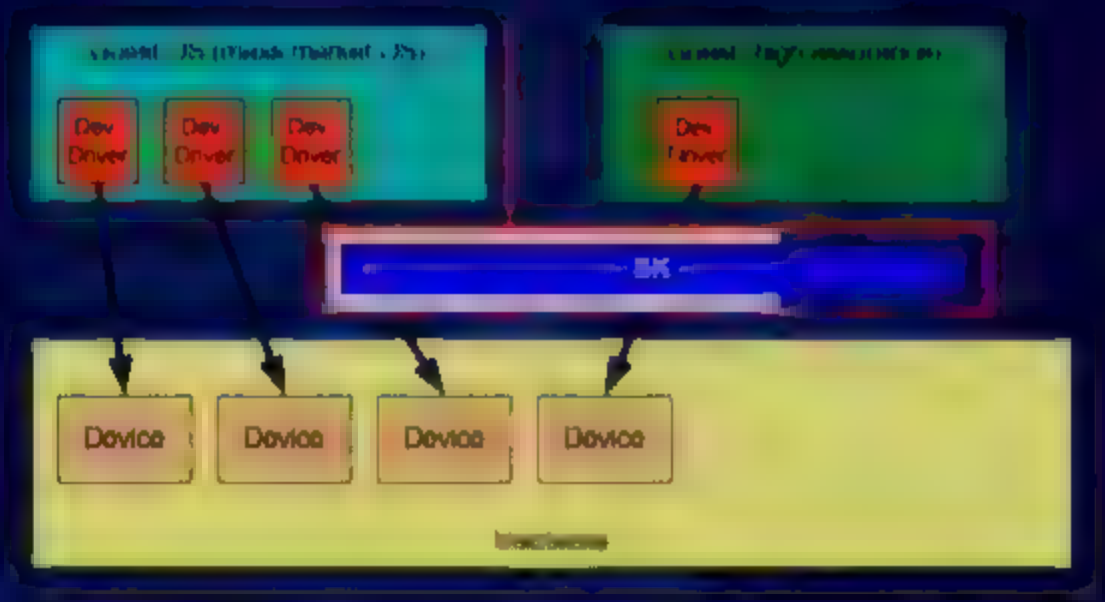
- Traditional high assurance systems
  - Often Orange Book as the main guideline
  - Examples
    - SE/VMS, SCOMP, KSOS, KVM/370
  - Not designed for today's mass market requirements
- Add security features to a mass market OS
  - Example: SE/Linux
  - What about assurance, given
    - The large size of the OS
    - The need to optimize for performance and features

# Dual System Approach

- Combine a mass market system and a high assurance system in one computer
  - Examples: Perseus, Secure Coprocessors
- Software implementations
  - Base layer hosts and isolates mass market OS and high assurance OS.
    - Base layer could be a VMM, an exokernel, a microkernel (Perseus)
- Requirements for the base layer
  - Must isolate hosted OSs (each OS can have exclusive access to some resources (pages of physical memory, keyboard)
  - High assurance
- Ability to securely load OS's into the base layer

# NGSCB Overview

- Dual System
- Software isolation layer (security kernel – SK)
- SK hosts and isolates guest OSs
- SK assigns devices (including DMA) to guest OSs
  - SK does not manage DMA devices
  - SK does not contain DMA device drivers
  - Reminiscent of Exokernels – but existing Exokernels manage DMA devices.
- SK exposes VMM-style machine interface for one guest OS (mass market OS – Windows).
  - Reminiscent of V=R mode on IBM mainframes.


Dev Driver
Dev Driver
Dev Driver
Dev Driver
SK
Device
Device
Device
Device

# The Rest of this Section

- How the SK manages DMA devices
- How the SK implements isolation
- Prototype implementation

# DMA: Device Problem

- We allow guest OSs to program DMA devices directly.
- But: Any guest OS in control of a DMA device
  - Can program the DMA controller
  - Obtain unrestricted access to all of memory by means of DMA.
- Need a new HW mechanism to restrain DMA devices.
- SCOMP followed a similar approach.

# DMA: Hardware Access Control

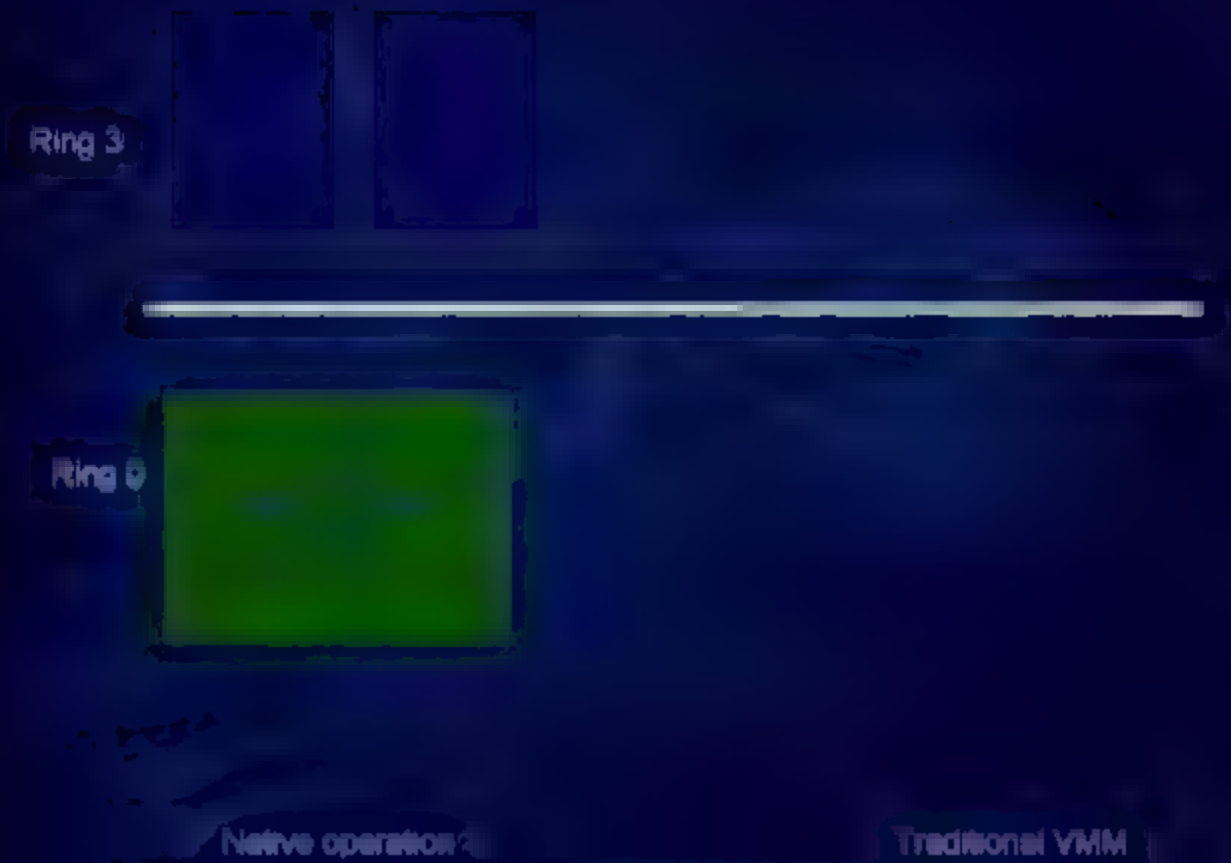
- For physical memory and memory mapped devices
- SK can specify for each page if DMA devices are allowed to access it.
  - 1 bit per page
- Enforced by the memory controller
- Limited expressive power
  - Trade off between complexity and functionality

# DMA: Management (in theory)

- The SK assigns devices to guest OSs for their exclusive use.
  - Memory mapped devices: Allow the guest OS to map the device into its address space.
  - Exokernel-style "secure binding"
- Interrupts
  - SK receives interrupts.
  - SK dispatches device interrupts to the guest OS that owns the device.
  - Guest OS handles interrupt.
- In practice (at least initially)
  - SK may not be able to control interrupt handling.
  - Static allocation of most devices to Windows.

# Isolation

- Requirements
  - Enable guest OSs to have exclusive access to resources (memory, devices)
  - Expose native hardware interface to at least one guest OS
  - Related to VMM requirements
- Why not just build a VMM?
  - Different treatment of devices (we expect; VMMs virtualize)
  - Existing VMMs work great for most tasks. But:
    - Some things do not work (device access).
    - Some things are slow.
  - x86 processors are not virtualizable. Building a VMM for the x86 is tricky.
- We introduce a new hardware assist: Ring -1.


Ring 3
Ring 0
Native operation
Traditional VMM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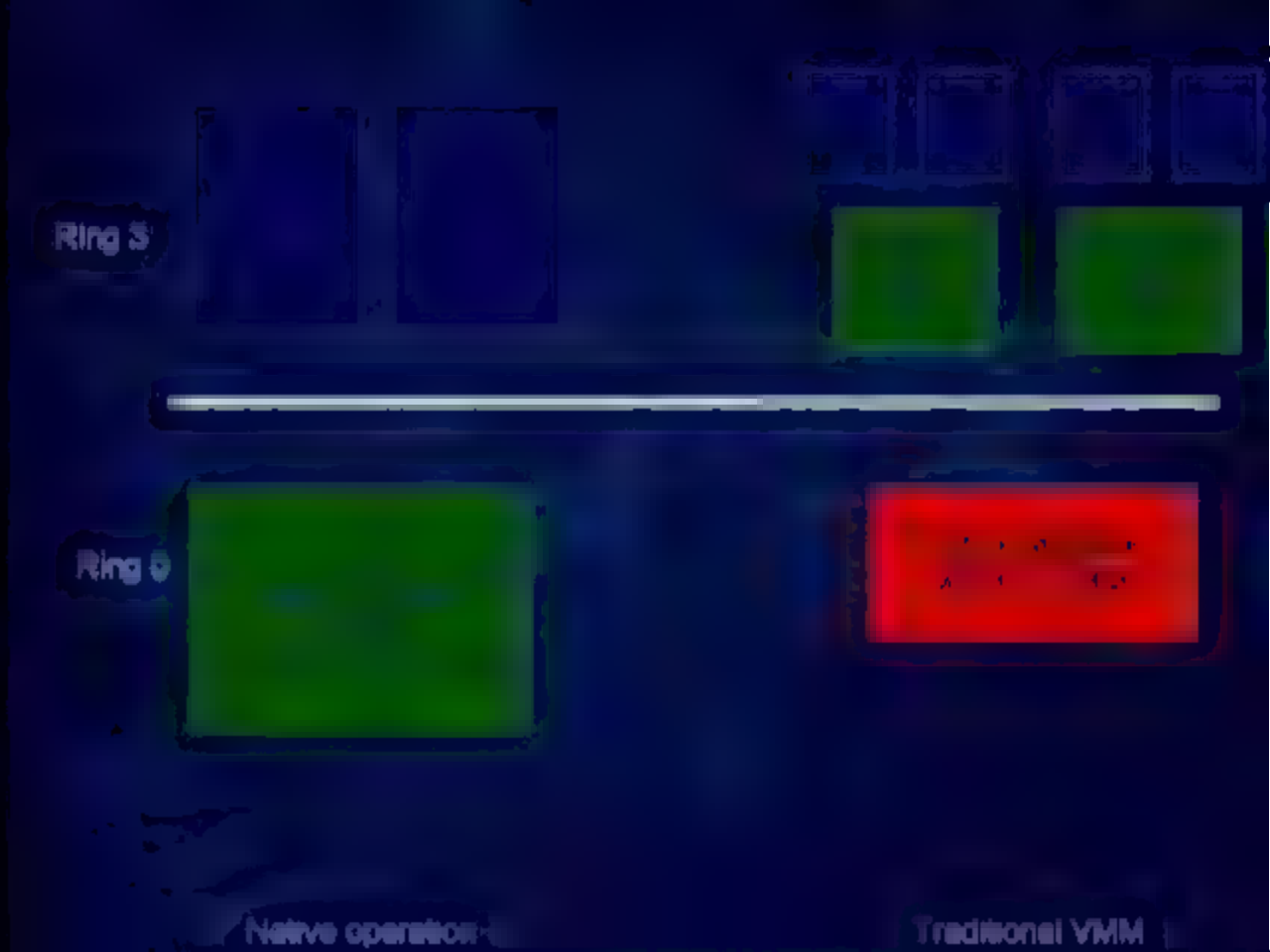
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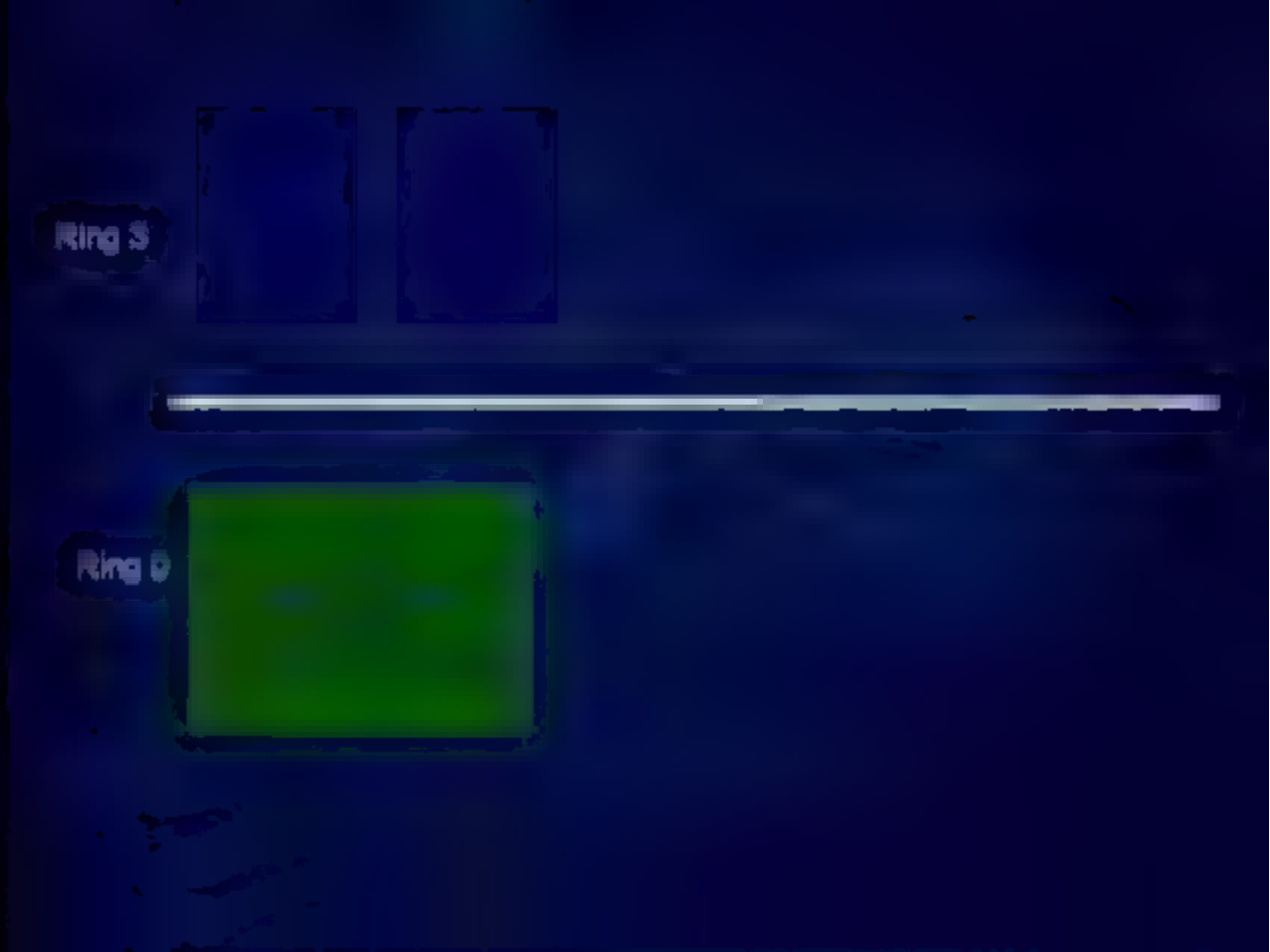
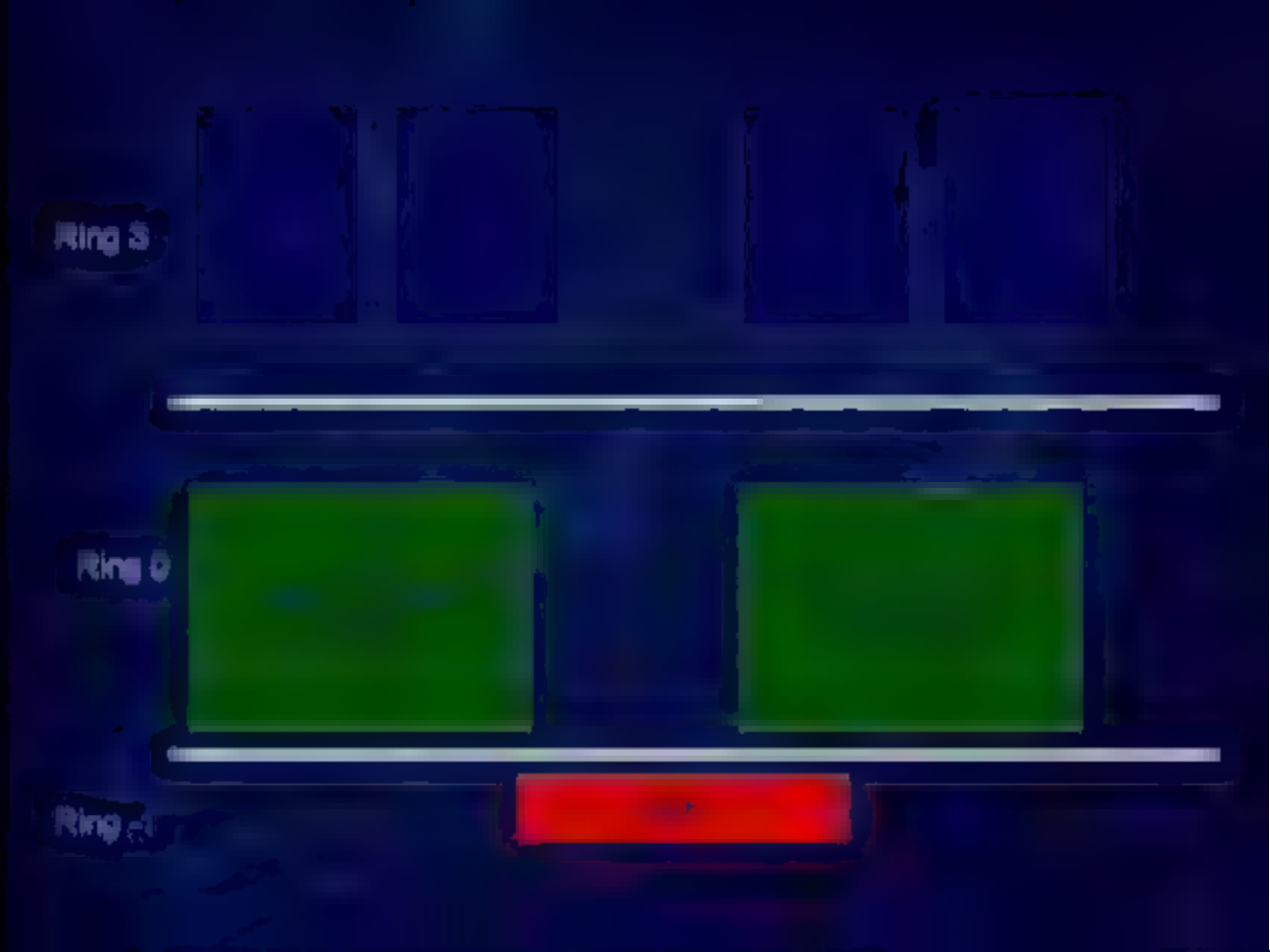

Ring 3
Ring 0


Ring 3
Ring 0
Ring -1


Ring 3
Ring 0
Ring -1


Ring 3
Ring 0

# Memory Isolation

- Every VMM has to do this in some form.
  - Classical algorithm: shadow page tables
  - V=R optimization for Windows "guest"
  - Further optimizations based on specific behavior of the Windows memory manager
- The SK grants a guest OS access to a resource by allowing it to map it.
- Every guest OS instruction that could change the virtual-to-physical page map traps into the SK
  - Write to CR3
  - Write using read-only mapping
    - The SK enforces that all mappings to page tables and page directories are read-only


PDBR /
CR3
Page
Directory
Page
Table
Other
Pages

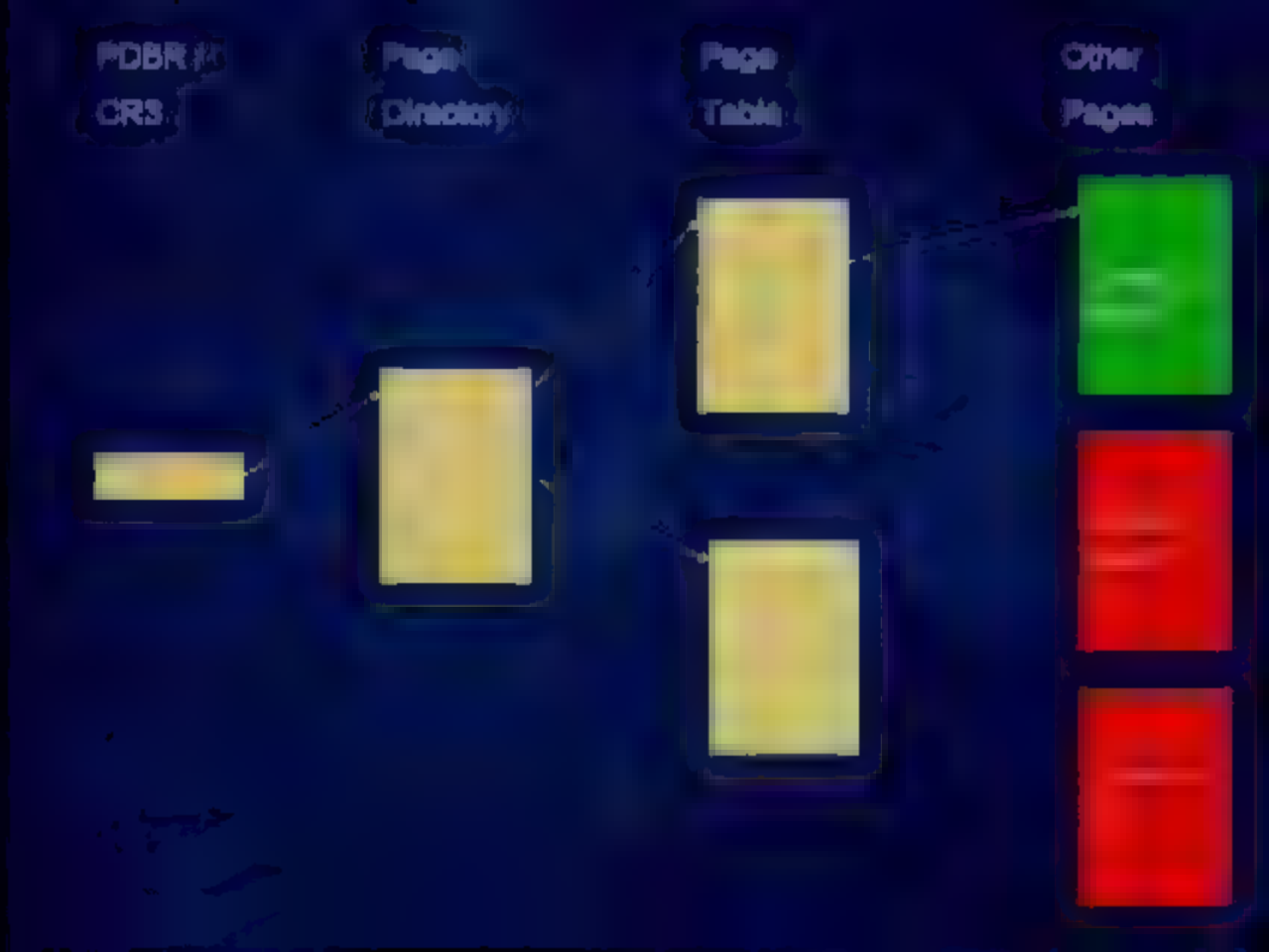

PDBR /
CR3
Page
Directory
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Table
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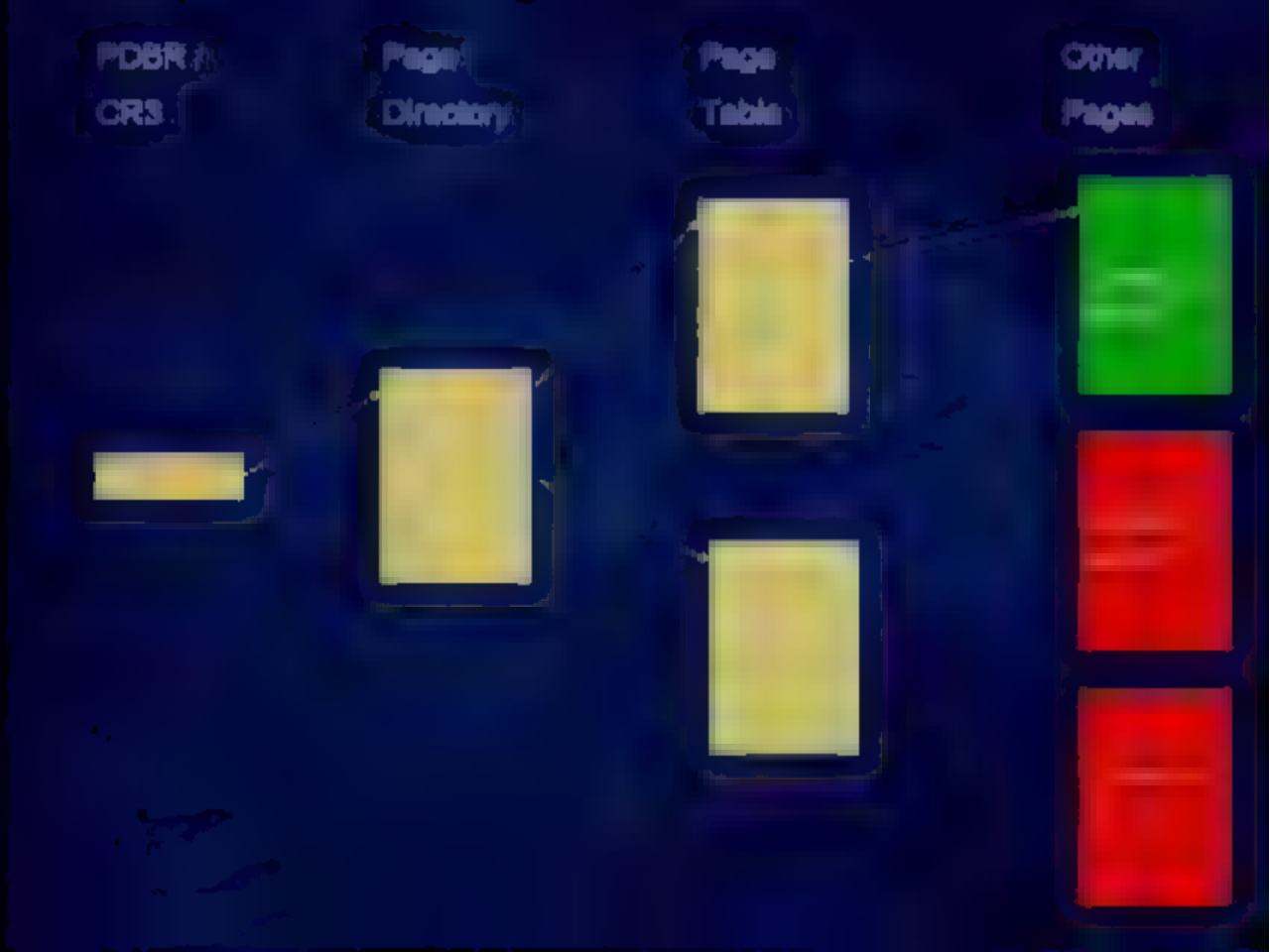
PDBR /
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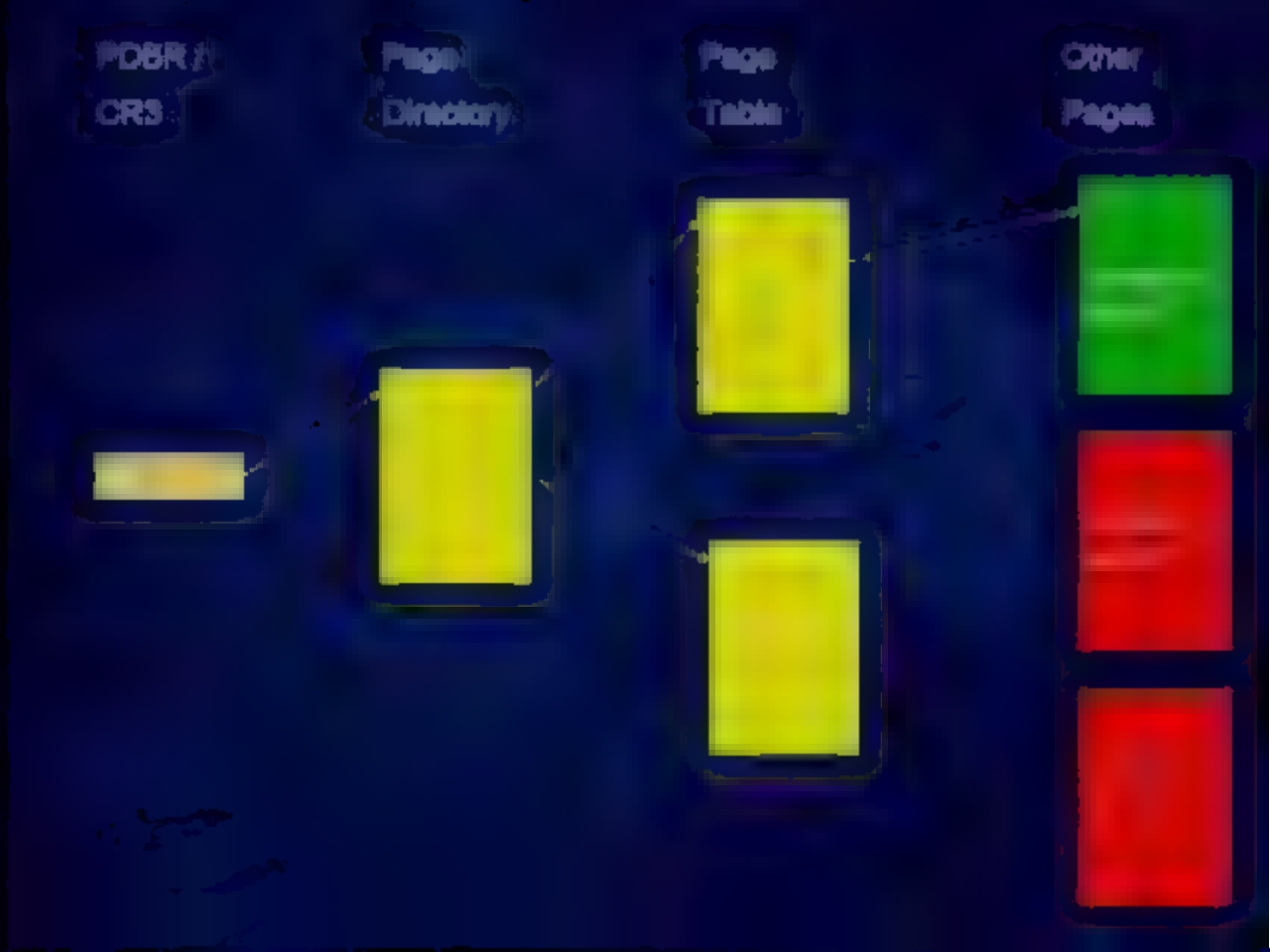
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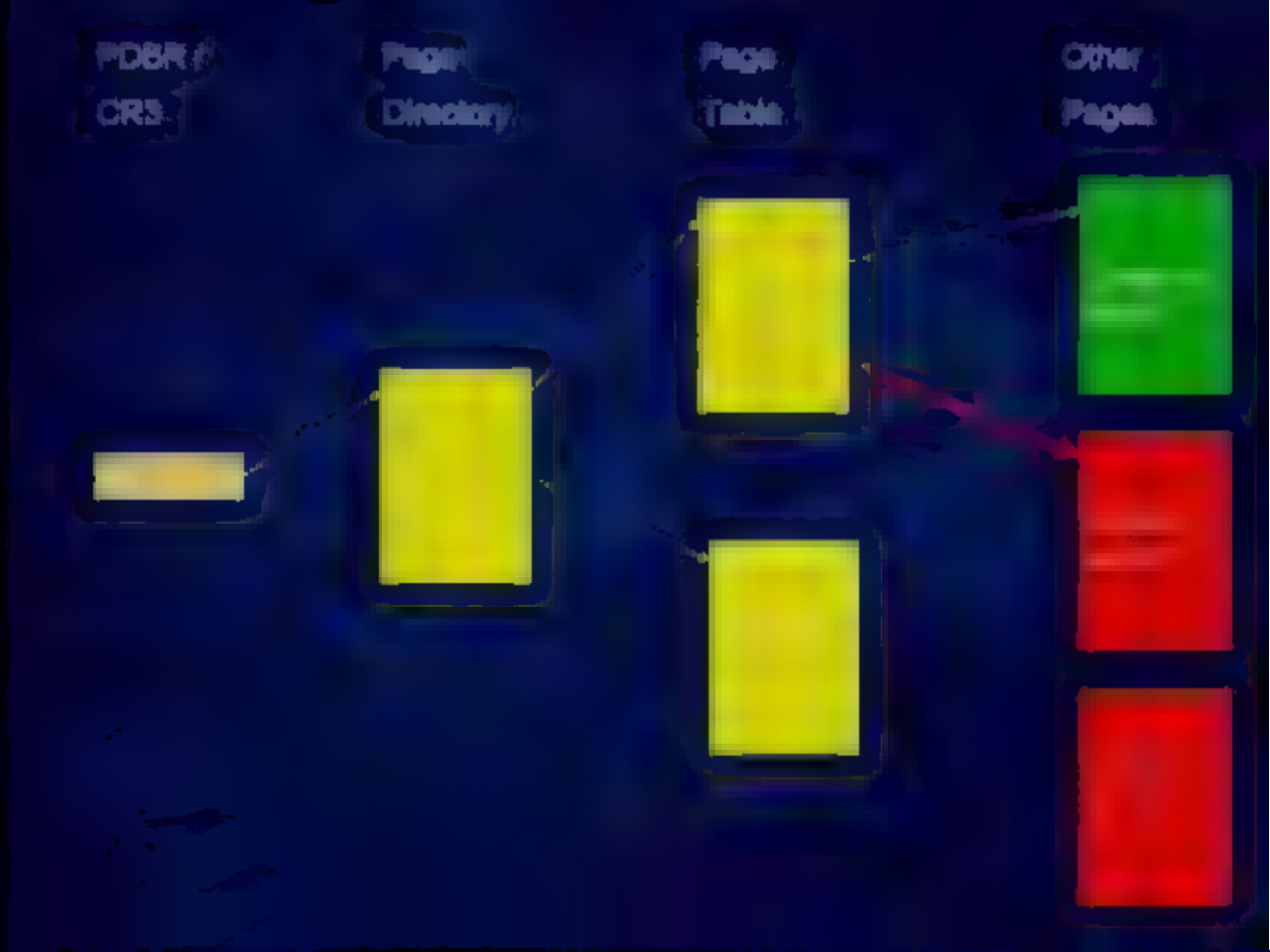
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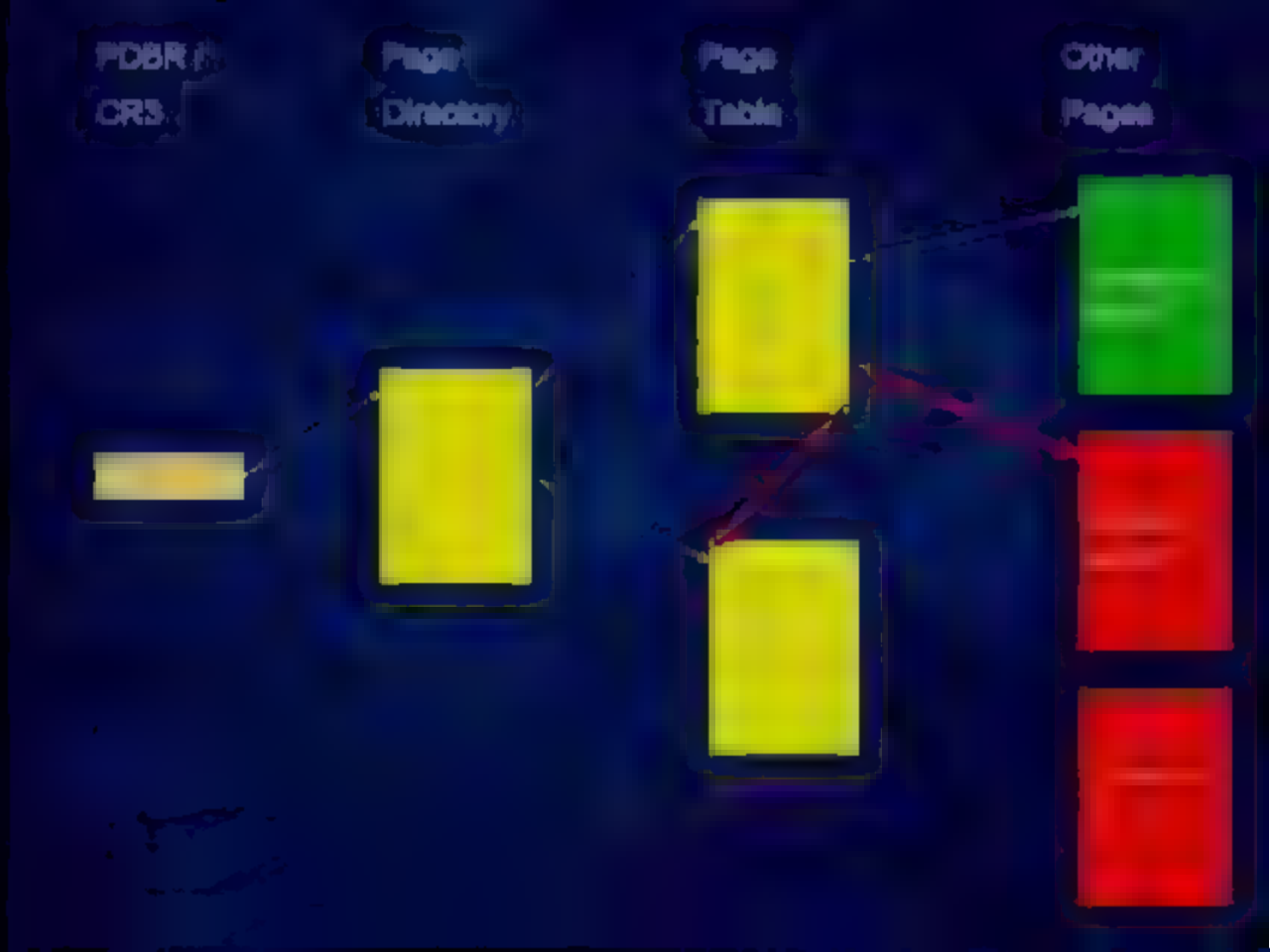
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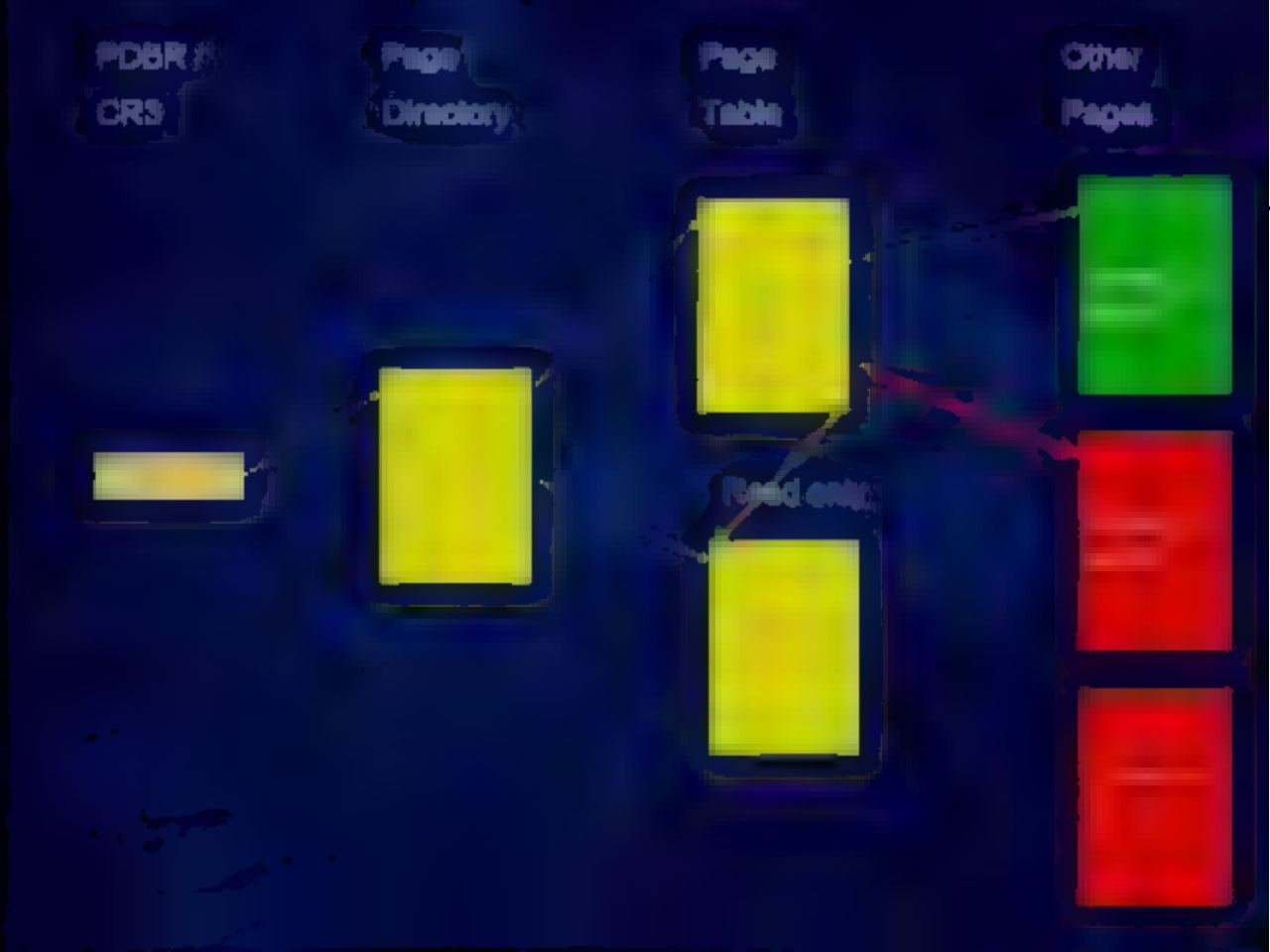
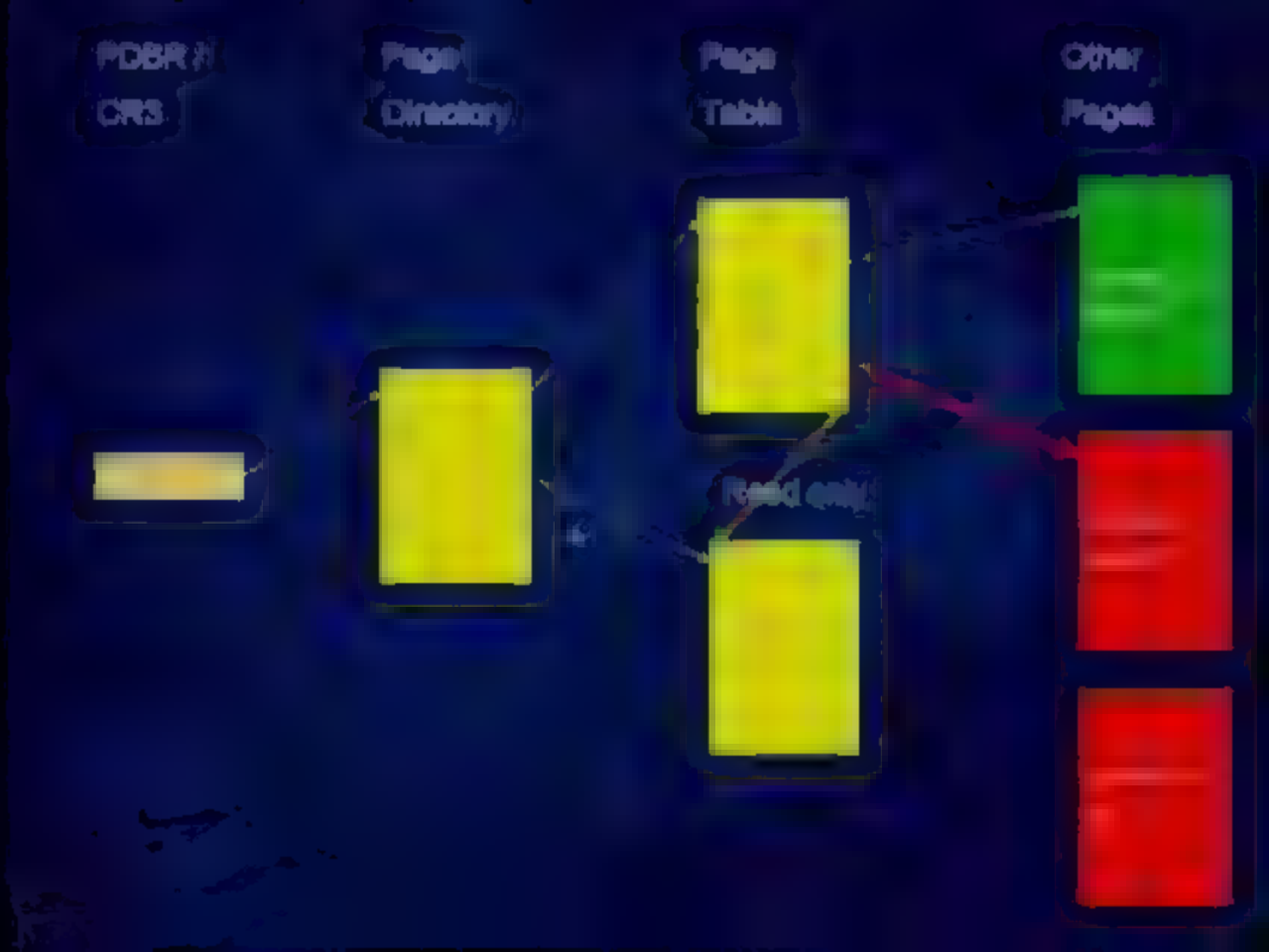

PDBR /
CR3
Page
Directory
Page
Table
Other
Pages

# Isolation: Optimization

- Use caching to reduce the average cost of trap handling:
  - D1: pages that are safe to be used as page directories
    - On Cr3 load: If the new page directory is in D1, no further checking is necessary
  - D2: pages that are safe to be used as page tables
    - Speeds up certain PD edits
  - Several reference counters


PDBR /
CR3
Page
Directory
Page
Table
Other
Pages
Read only

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# SK Prototype

- Implemented isolation and hosting components of the SK
- Test bed:
  - Unmodified PC hardware
  - Instrumented version of Windows XP
    - Write to CR3 → trap to SK
    - Write fault → trap to SK
    - Process destruction → notify SK
    - Delay loops and artificial TLB flushes to account for HW differences
- Goals
  - Check for surprises in the behavior of Windows.
  - Check that our validation methodology is feasible.
  - Test performance; gather data for optimizations.

# Prototype Implementation

- About 2000 lines of C code
- Core PTEC algorithm: about 1000 lines
  - Formally specified in first order logic
  - Verified using a theorem prover
  - C code derived from formal specification
- Prototype is not optimized!
- Test Bed for experiments
  - 2.5 GHz Pentium 4
  - 1 GByte DDR RAM
  - nVidia GeForce2 graphics card; WD400BB hard disk

# Event counts

| Event | Count | Avg. time (µs) |
|---|---|---|
| CR3 load (new) | 83 | 2006.3 |
| CR3 load (from DT cache) | 971,391 | 0.234 |
| PD edit | 8,860 | 19.726 |
| PT edit | 8,062,636 | 1.66 |

Events counted over one run of the Content Creation Winstone 2002 benchmark program.

# Micro Benchmarks

| Benchmark | WinXP native | SK no delay | SK 1000 delay cycles TLB Flush | VMware |
|---|---|---|---|---|
| Disk I/O (MB/s) | 40.07 | 40.02 | 40.07 | 25.46 |
| DirectDraw (frames/s) | 18.64 | 18.00 | 18.64 | Failed |
| GDI line draw (ms) | 1.85 | 2.40 | 2.56 | 14.15 |
| Context Switch (ms) | 4.28 | 6.51 | 6.86 | 28.34 |
| Memory Allocation (ms) | 1.27 | 11.85 | 12.87 | 10.80 |
| Process Creation (ms) | 2.70 | 7.00 | 7.76 | 7.81 |

# Synthetic Benchmarks

| Benchmark | WinXP native | SK no delay | SK 1000 delay cycles | VMWare |
|---|---|---|---|---|
| Business Winstone 2002 | 25.7 | 24.6 | 24.2 | 22.5 |
| Content Creation Winstone 2002 | 35.0 | 33.6 | 33.4 | 27.9 |

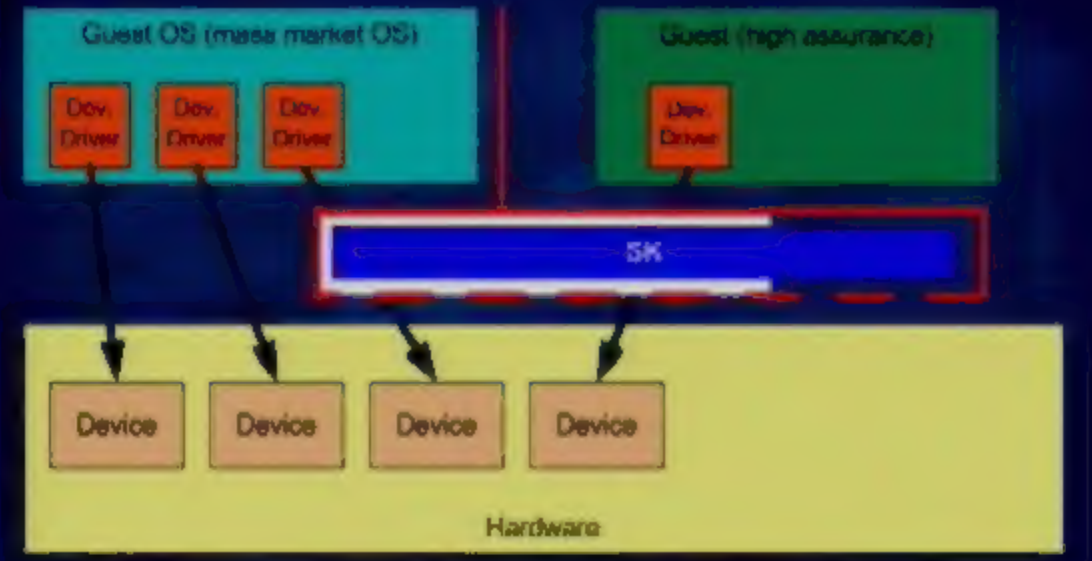
**Business Winstone:** Word, Excell etc.

**Content Creation Winstone:** Adobe Photoshop, Adobe Premiere, Windows Media Encoder, Netscape Webbrowser

# Position Check

- Dual System
  - One mass market guest
  - One high assurance guest
- Very small isolation layer (SK)
  - Fast, verifiable, compatible with legacy
  - Device management left to guests
  - No complicated virtualization schemes
- Require changes to chipset and CPU
  - HW enforced access restrictions for DMA devices
  - Ring -1 and privileged instructions

# The High Assurance Guest



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